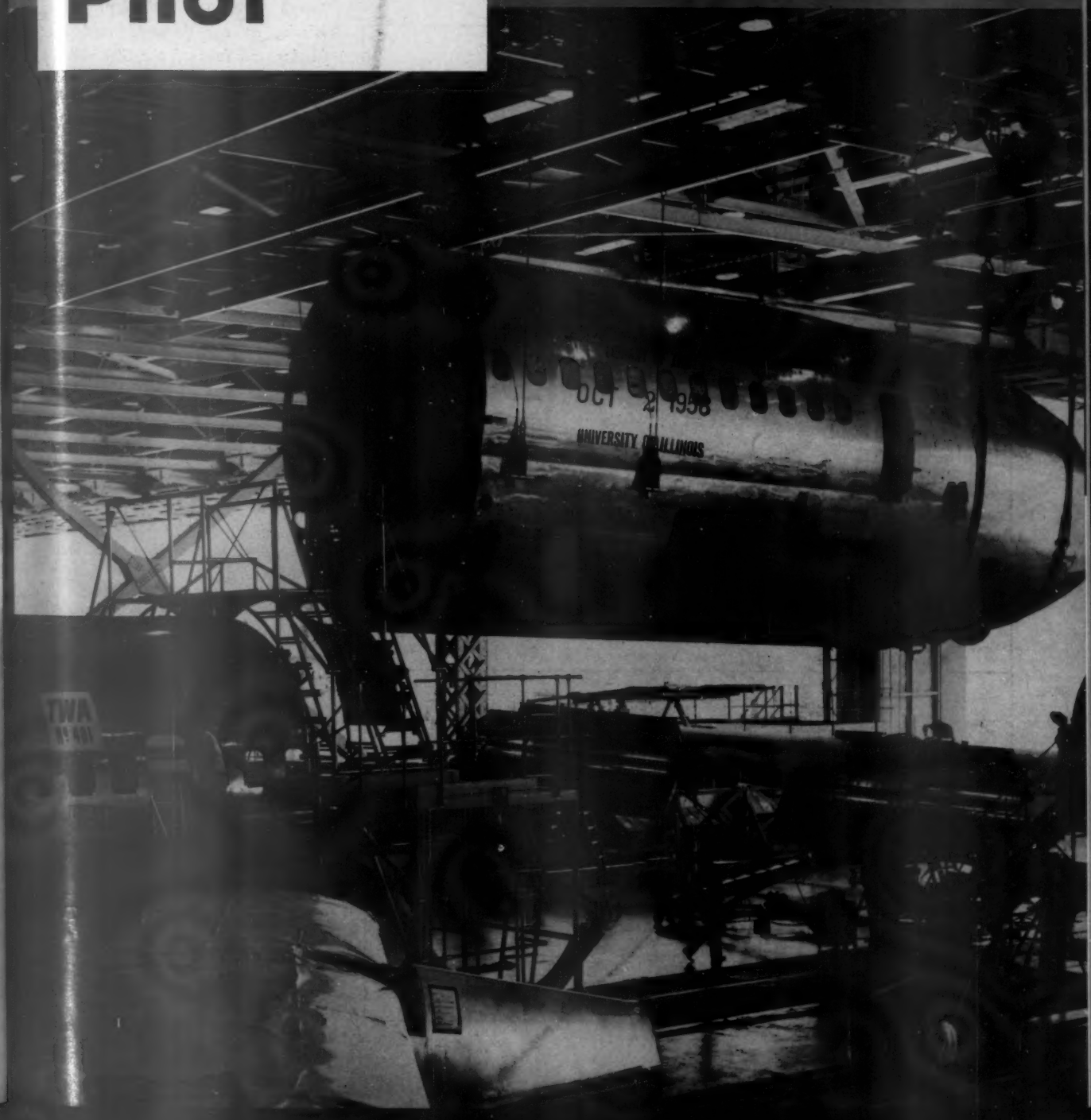
The Air Line Pilot

SEPTEMBER, 1958



The Air Line Pilot

SEPTEMBER, 1958

Vol. 27, No. 9

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ED MODES, Editor AL LEACH, Asst. Editor

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IN THIS ISSUE

ATC For Civil Jets.....Page 3

"Pilot Error" Handy Statistical Stigma.....Page 5

Digest of News.....Page 6

Know Your Officers.....Page 7

The ALPA Camera.....Page 8

Pilot Tip . . . NO Self Medication .....Page 9

Along The Line .....Page 10

ALPA'S Regional Office, Coral Gables, Fla.....Pages 12-13

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On the Cover

Trans World Airlines' first Boeing 707 Stratoliner is shown on the manufacturing line at Boeing Airplane Company's Transport Division, Renton, Wash., as the forward and center fuselage sections of the 600 miles per hour jet airliner are joined.

An order for eight Boeings has been announced by TWA and plans are to place the first airplane in service early in 1959, probably on transcontinental, nonstop, first class flights.

The exact seating arrangement in the first TWA jetliners has not been determined but it is expected to be in the more than 100 capacity.

Jets for international service also have been ordered by TWA, according to reports, and their jet fleet will be augmented with 30 Convair 880s.

TWA is one of 15 world air lines which have Boeing jetliners in operation, in production, or on order. The U. S. Air Force also has orders in for the civilian version of the military jet bombers.

Throughout the development of the Boeing jetliner, an ALPA 707 Evaluation Committee worked closely with the company and the government in recommendations on the safety and performance aspects of the airplane.

Members of the committee are:

R. Holm (PAA), chairman; A. Shelly (CAL), H. Thurston (TWA), W. Records (AAL), A. Place (BNF), C. Kraemer (AAL), C. Daudt (AAL), T. Patecell (PAA), L. Mouden (BNF), R. Stone (UAL), S. Terrell (PAA), R. Adickes (TWA), W. Betts (BNF), and T. Linnert, ALPA engineering and safety department.

ATC For Civil Jets

By Tirey K. Vickers
CAA Technical Development Center

Jet Transport Simulation Studies By Research Controllers At CAA Technical Development Center, Indianapolis, Ind., Preview Jet-Age Air Traffic Control

J-Day is on the way. Chances are, you've been awaiting this event with a lot of curiosity. How will the civil jets change the air traffic control picture? What are their special characteristics and limitations? What new techniques or procedures will they require? How will this affect your workload—your job?

So far there has been very little opportunity to obtain actual operational experience in feeding civil jets through congested areas under IFR conditions. However, if we know their flight characteristics, we don't need the actual aircraft to determine what will happen when they hit the system. For a few dollars an hour we can feed these characteristics into the Dynamic ATC Simulator at the CAA Technical Development Center, and generate the same traffic problems that would result from a flock of $900-per-hour DC-8's, 707's, or 880's.

During the past few months our teams of research controllers have been clearing thousands of civil jets through a number of complex terminal area and air route sectors, simulating traffic conditions typical of those forecast for the next five years. This activity is giving us a solid preview of what civil jet problems are going to look like through

the glass end of an ASR or an ARSR. More important, it is providing an opportunity to develop a number of possible solutions to these problems, and to see just how effective they will be when the chips are down.

We're still learning—but already we have uncovered a number of useful items which are going to have a vital effect on civil jet operations. We have also shaken down a number of control techniques which may simplify your job some day. So gather 'round and we'll clue you in on the highlights.

As a class, the new family of jet transports will be larger, heavier, and more powerful than the commercial aircraft in general use today. As shown in Fig. 1, they will fly higher

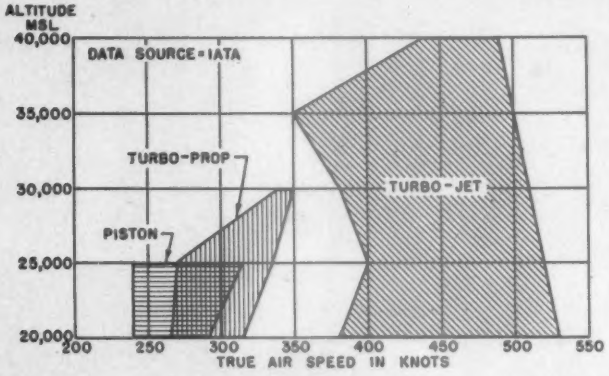

Fig. 1. High altitude cruising performances of new civil transport aircraft

and faster than any other type of civil aircraft. If you're not used to handling jets, their higher speeds will present a few problems. First of all, the rates of closure will be higher and the problem of over-takes will increase. Turning rates at high speed will be considerably lower than those normally used in conventional flight operations. Besides increasing the amount of airspace required for any maneuver, this factor will have an even more noticeable effect from the radar controller's standpoint—you'll wait much longer for an aircraft to complete a turn to a desired heading.

Workload Speeded

All these factors will have the effect of reducing the amount of time available for handling your normal workload. Data posting will have to be speeded up, as flight time between fixes usually will be less than that taken by other aircraft on the same route. Decisions will have to be made farther ahead of the aircraft, due to the decreased flight time and the lack of aircraft maneuverability at high speed. Simulation tests show that this business of getting used to the increased operating tempo—the job of "staying ahead of the airplane" will be one of the most important factors which the controller will have to learn in handling the civil jets.

The large number of altitude levels crossed by jet aircraft in climb or descent will often make the use of altitude vacatting reports impractical for less than 5000-foot increments of altitude. Fortunately, the increased climb and descent rates of such aircraft should reduce delays from this cause.

Figure 2 shows the extensive distances which will be covered by jet aircraft in climbs and descents. As altitude separation cannot be used where one aircraft is crossing the altitude level of another, the long climb and descent distances of jet aircraft will increase greatly the area in which lateral separation must be provided, either by radar coverage, or perhaps, some day, by the use of a navigation system which can provide passing lanes.

Although the climb and descent rates of jet aircraft normally will be higher than those of other civil aircraft, their forward speeds will also be correspondingly higher. As shown in Fig 2, the lower portions of their climb and descent paths will often coincide with those of other aircraft. In such cases a severe overtaking problem will occur unless lateral separation can be used.

Figure 2, shows the wide variation in climb distances of

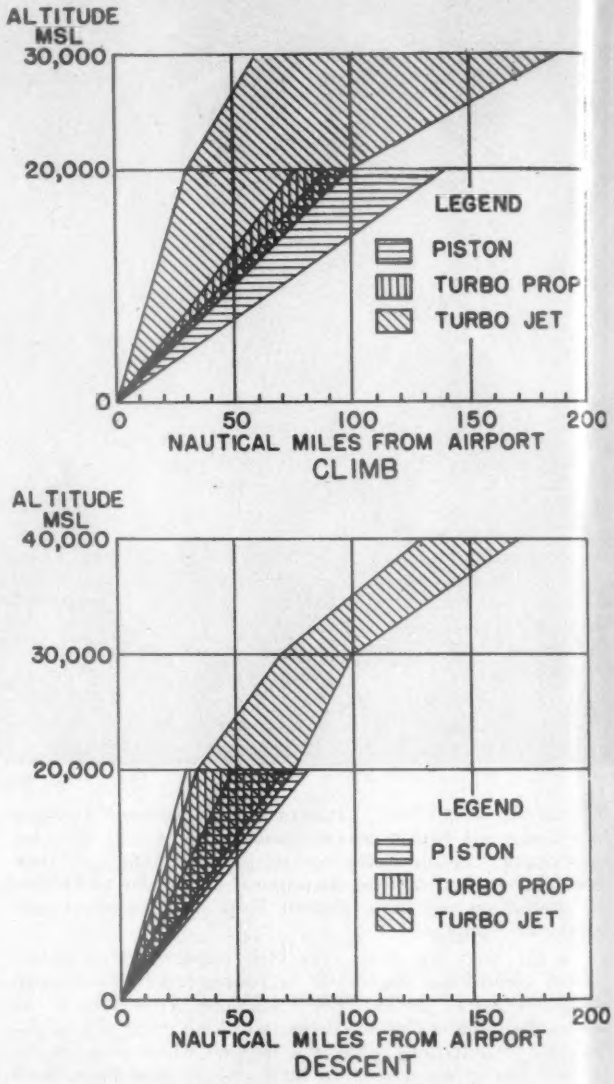

Fig. 2. Climb and descent distances of new civil transports (still air). Data source: ICAO.

the civil jets. For example, although some aircraft will reach 20,000 feet only 30 miles out, others may require 100 miles to get this high. There are three reasons for this variation:

a. Fully loaded, some of the new jets can carry as much as 40 per cent of their weight in fuel. Lightly loaded short-hauls will have a large amount of excess thrust, resulting in a much higher rate of climb than long-haul aircraft loaded to the gills.

b. The thrust output of turbo-jet engines is extremely sensitive to air temperature. Warmer temperatures result in less thrust and lower climb rates.

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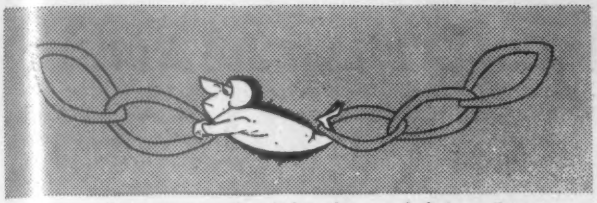


"The pilot is only a link in the causal chain . . ."

"Pilot Error" Handy Statistical Stigma

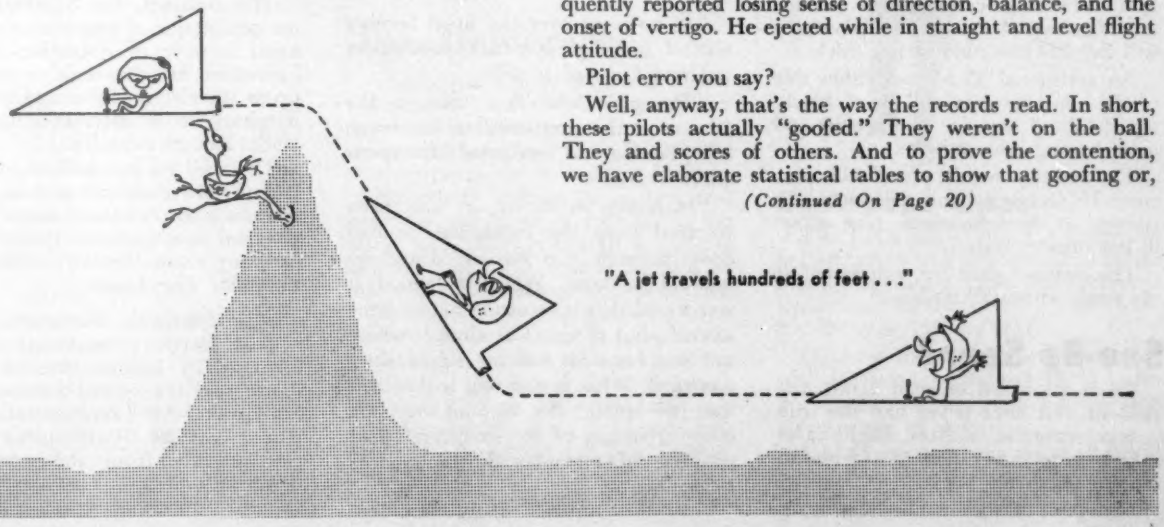
By Jeff Sutton

(Copyright 1958, Ziff-Davis Publishing Co.)

PILOT error is a careless phrase with an implication which should be eliminated from the aviator's lexicon. It is this writer's opinion that too many accident investigators and statisticians are burying a lot of things besides pilots when they use the term.

The term generally concerns unfortunate souls who are not presently around to defend themselves. It is used carelessly in accident reports, statistical tables, newspapers, trade journals, and even in hangar-type conversation. As a group, there is none less forgiving than pilots whenever misfortune befalls a brother aviator. Strong words, you say? Well stick around and maybe we can do some convincing.

Recently, two young pilots met disaster in a lightplane accident. They were from a field where this writer does some flying. There were no witnesses to the crash. Bare minutes after it became known, the "Board of Aviation Types" at my field had met, discussed and fixed the blame. Their indictment? Pilot error. The pilot, they said, was an ex-Air Force hotrock who thought he was pushing some high-powered equipment around. They decided a stall in a tight turn at low altitude was the direct cause of the accident.



"A jet travels hundreds of feet . . ."

Fortunately, an alert mechanic stumbled onto the real reason. The front drag strut fitting had failed and led to a major structural failure which, in turn, had resulted in the "hot-rock's" accident.

A transoceanic airliner landed at Shannon Airfield in Eire and taxied toward the unloading zone. The pilot ordered "flaps-up." The co-pilot pulled the gear control handle to "wheels-up" position. The airliner dropped to the runway and was badly damaged.

Normal Take-off—Crash

An executive pilot made a normal night take-off and retracted landing gear as airspeed increased to 160 mph and altitude to 300 feet. The pilot read the gyro-horizon indicator as showing a slight nose-up attitude. A few seconds later the plane hit the ground in a level attitude, with an impact which caused later investigative reverberations.

The pilot of a McDonnell F3H2 Demon entered an overcast at 7,200 feet and switched to the gauges. He subsequently reported losing sense of direction, balance, and the onset of vertigo. He ejected while in straight and level flight attitude.

Pilot error you say?

Well, anyway, that's the way the records read. In short, these pilots actually "goofed." They weren't on the ball. They and scores of others. And to prove the contention, we have elaborate statistical tables to show that goofing or,

(Continued On Page 20)

Digest of News and Views in Aviation

Concrete To Cover Asphalt On O'Hare Jet Runway

THE City of Chicago recently awarded contracts totaling more than $3 million to overlay the southeast-northwest asphalt runway at O'Hare International Airport with concrete in expectation of commercial jet operations there early next year.

Approximately three years ago when Chicago began plans for construction of the runway, ALPA members and representatives of the ALPA engineering and air safety department, appeared before the Chicago city council urging that the runway be constructed of concrete.

However, for economy reasons, the original estimate of $2,400,000 for a concrete runway was turned down and a $1,700,000 contract for asphalt construction was awarded. With the new construction, the runway will cost $2 million more than the original estimate for concrete.

The new "rush," project entails overlaying the 8,000 foot runway, 200 feet wide, with concrete. The runway will be lengthened 838 feet. Warm up pads, new taxiways, drainage and electrical work are included in the contract.

The runway ends will be paved with concrete 15 inches thick, 200 feet wide and approximately 1,000 feet long. A strip 100 feet wide down the center line joining the two ends will be laid in 11-inch thick concrete. For 25 feet on either side of the 100-foot pavement will be concrete nine inches thick.

An additional 25 feet on either side of the concrete area will be of blacktop stabilized area for emergencies and maneuvering into taxiways.

The taxiways will be paved with concrete 75 feet wide and will enter the runway at three locations, plus access to the runway ends.

The contract calls for completion of the work within 90 days.

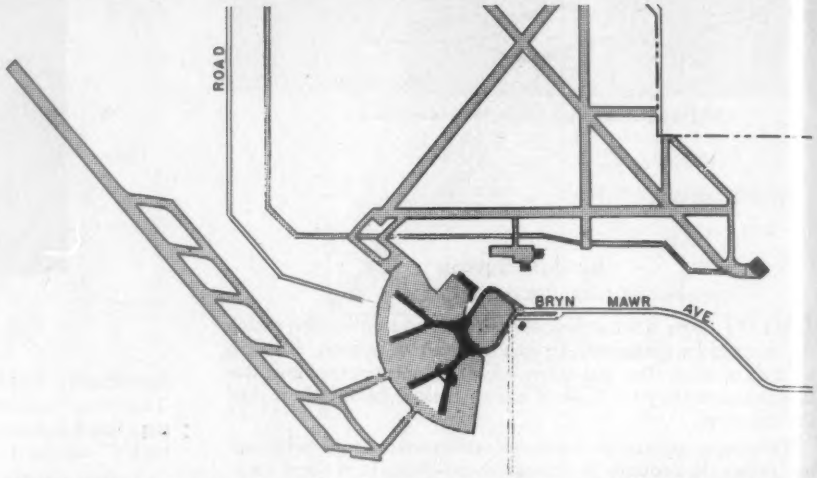


DIAGRAM of the Southeast-Northwest jet runway at O'Hare International Airport, Chicago, which will be recovered with concrete after it was determined the present asphalt construction is not suitable for heavy jet airliners.

See-Be Seen?

We've all heard or read about this incident, but have never had the true facts presented to us. Now, Flight Safety Foundation gives them to us from an authentic source.

"The pilot of a jet bomber was flying at 30,000 feet on a clear morning. He made a slow turn and was startled to see three other bombers approximately a mile away on a collision course with him. Before he could react or alter course, he shot through the formation missing the nose of the first aircraft, flying under the second and over the third.

"As he went over the third bomber one of his engines struck part of its tail and knocked it off.

"The pilot who flew through the formation then returned to his home base, landed and recounted his experience.

"Inasmuch as no report had been received from the formation he had flown through it, it was called and requested to land. When it landed it was found that it consisted not of three aircraft, but of six. The aircraft whose tail had been hit was not significantly damaged. What is amazing is that neither the pilot, the co-pilot nor the observer in any of the six aircraft had seen the other bomber fly through the formation!"

From, Plane Facts

New Electronic Aid

An automatic air-ground communications system designed to cut air traffic delays and help solve the problem of mid-air collisions will be developed by the Radio Corporation of America under a contract awarded by the Airways Modernization Board.

The contract, for $1,400,000, calls for production of experimental equipment capable of obtaining flight information by electronic means from up to 500 aircraft in two minutes. This is twenty-five to fifty times the present voice-channel capacity.

The need for automatic communications between aircraft and the ground to reduce the collision hazard was emphasized in a special aviation facilities planning report recently submitted to President Eisenhower.

Electronic, Automatic

J. M. Hertberg, marketing vice president, RCA Defense Electronic products, said the system—known as the Air-Ground-Air Communications System (AGACS) — will query aircraft electronically from the ground for flight information. The answers, provided by special airborne equipment,

Know Your Officers

Capt. C. C. (Chuck) Spencer, Pan American World Airways, Inc., has been reelected Vice President of Region I of the Air Line Pilots Association. He has held the position for two and one-half years.

Captain Spencer also has been Safety Chairman, Council Chairman, and MEC Chairman in the ALPA organization.

His area covers New York, New Jersey, Pennsylvania, Massachusetts, Maryland, and parts of Virginia, and Washington, D. C.

Spencer, who flies the North Atlantic for Pan Am, is 47 years old, and began his flying career in Casper, Wyo., in 1925 while still in school. From 1930 to 1934, he operated a flying school and charter service in New Mexico and Arizona. In 1937, he joined Braniff Airways, following service as a pilot for an oil company in New Mexico.

The ALPA regional vice president joined American Export Airlines in 1942. American Export later became American Overseas, and then merged with Pan American in 1950.

Spencer

Spencer and his family live in Port Washington, Long Island, N. Y.

will come automatically and instantly, without intervention of the pilot for routine questions.

Voice communication will remain in use for non-routine messages and for emergency use in aircraft not equipped for the mechanized communications, AMB spokesmen said.

The new system will operate in conjunction with a ground-based data-processing display system being developed for AMB by General Precision Laboratories, Pleasantville, N. Y. This system will either store the flight information for use in up-dating flight plans or make them immediately available to the traffic controller.

Study Joint Use

As part of the AGACS development program, studies will be made to determine the most satisfactory and economical means of adapting present military and civilian aircraft communications equipment to use in the new system.

The contract calls for the experimental equipment to be developed by August, 1959, and tested and modified as needed during the rest of the year. It is planned that the system then will go into operation in the East Coast area in 1960.

UAL University

A long-time United Air Lines dream —their own "university"—came closer to realization last month with announcement of plans for a $1,000,000 training center to be built at Denver.

The school will be the largest and most comprehensive of its kind in the world, with facilities to train new stewardesses and flight officers as well as supervisory and management personnel.

According to T. Lee, Jr., Vice-President-Education and Training, the "United University" will be built on a 6.9 acre plot leased from Colorado Woman's College. (For those familiar with Denver, the area is bounded by Montview Boulevard and 21st, Quebec and Olive streets.)

The main facility will consist of two separate buildings. The larger of these will house stewardess trainees, management trainees and a permanent teaching staff. Present plans call for a structure two-and-a-half stories high with two housing wings separated by an area for classrooms, recreation lounges, cafeteria and banquet hall.

A smaller building will house United flight crews, who remain in Denver for a longer period of training than other groups. Their classroom work will continue to be handled at the Flight Training Center at Stapleton Airfield.

Other facilities on the "campus" are expected to include a swimming pool, several tennis courts and a parking lot for 115 cars.

Lee predicts that by 1965 United will be training approximately 2,900 persons in Denver each year. Included will be approximately 680 stewardesses in five-week training periods, 60 flight crews in 9-to-15-week periods and 1,260 supervisory and management employees in one-week periods.

Detailed plans for the school now are being worked out with construction expected to begin next year and be completed by 1961. In the meantime, United will continue to operate its training center at Cheyenne.

CAA Jobs Open

The CAA plans to make many appointments from a new examination for Flight Operations and Airworthiness Inspector. Salaries will range from $5,958 to $8,330 per year.

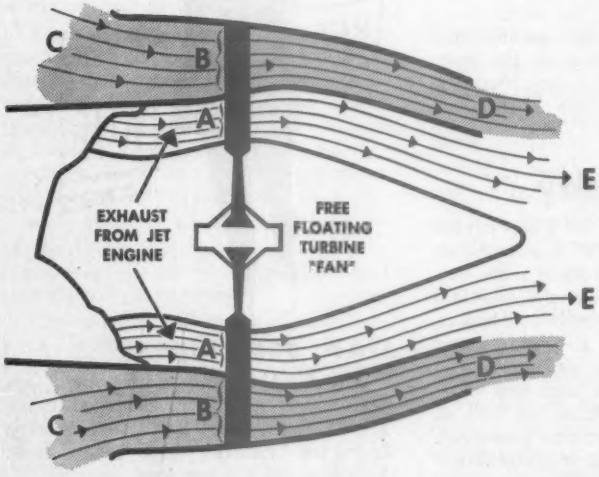
Duties of these positions deal directly with the safety of human life in transportation by air and involve a considerable amount of travel.

Full information may be obtained at post offices or the U.S. Civil Service Commission in Washington, D.C.

HAWAIIAN Airlines' Stewardess Rhanda Blaisdell exemplifies true Polynesian beauty. She is of Hawaiian, French, Spanish, German and English extraction.

EVEN during relatively quiet flight periods, Washington National is a busy place as shown by the thousands of vehicles parked in the vicinity of the terminal building.

NEW BELL Aircraft automatic all-weather landing system picks up jet from two to four miles from end of runway and controls it through automatic pilot all the way to touchdown.



FAN JET engine of GE (CJ805-21) has static takeoff thrust of 15,000 pounds. Conventional exhaust flow (A) rotates fan, causing outer section (B) to draw additional air into by-pass (C). Accelerated exhaust (D), adds to conventional engine thrust, thus providing increased engine thrust at lower jet velocity with resultant fuel economy and takeoff efficiency.

PILOT A. M. (Tex) Johnson, left, of Boeing tells Wilbur L. Morrison, Pan American executive, how big 707 jet liner flew 1,300 miles from Boston to Miami in 2 hours, 48 minutes at a speed of 525 mph.

Pilot Tip . . .

NO Self Medication

SEVERAL of the recent advances in medicine, termed boons to the general public, have found to be anything but a boon to the pilot in the cockpit. Today, antihistamines are almost as commonplace in the family medicine chest as aspirin, and their value in combating a cold or mild allergy is unquestioned. However, there are side effects to their use that are anything but harmless to the person who is flying such a complex piece of machinery as the airplane.

Another so-called "great boon" to the public is the tranquilizers. While these are considered useful in the treatment of mental or emotional disturbances, anxieties and tensions, they also possess side effects which make their use harmful to anyone controlling an airplane.

Antihistamines

Most of these do a better job of making you drowsy than an actual sleeping pill. Tests conducted by the Air University School of Aviation Medicine showed that "in their ability to produce drowsiness, these antihistamines are as effective, 90 to 130 minutes after medication, as any of the sedatives . . ." One recent pilot-error accident was attributed to the pilot's use of these cold-combating drugs. He had taken antihistamine against the advice of the flight surgeon he had consulted the night prior to his mission.

Tranquilizers

The pros and cons of the use of tranquilizers are still being studied by medical groups, and so a final analysis is not possible. It is acknowledged, however, that these drugs do replace worry and anxiety with a pleasant feeling of well-being. But as with the antihistamines, it is the secondary effects of these medicines that make them incompatible with flying safety. Certainly this is not the way to get the spirit of tranquillity that pilots have so long sought in operating aircraft.

Chloropromazine (Thorazine): These are useful in the treatment of emotional and mental disturbances and as an aid in anesthesia. However, their use produces several side reactions which conflict with pilot safety, i.e., changes in blood pressure and heart rate, blurred vision, dizziness, fainting, incoordination, nasal stuffiness, fatigue, stomach and bowel upsets and sensitization of the skin to sunlight. Another one, Promazine (Sparine) is similar to Chloropromazine and shares many of its side effects.

Reserpine (Rauwolfia serpentina, rauwiloid, serpasil, reserpoid): These are used in the treatment of high blood pressure and are also valuable in the treatment of emotional disorders. Their side effects, however, are similar to those of Chloropromazine, except they do not blur vision or sensitize the skin.

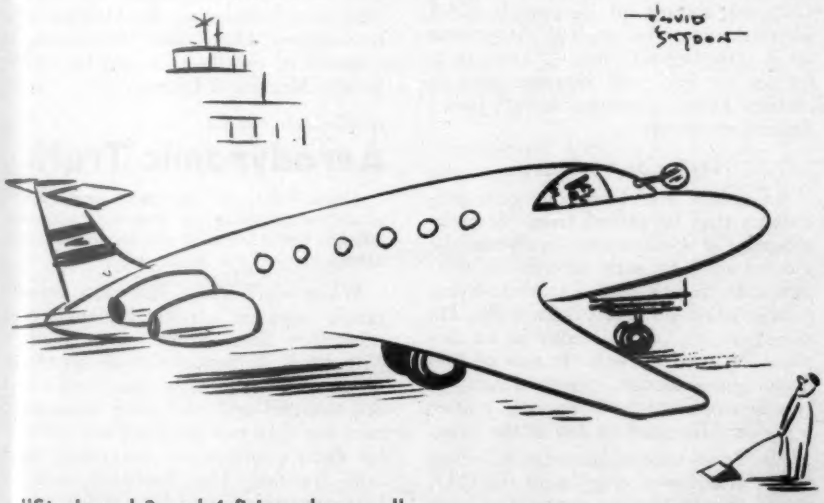
Miltown

Meprobramate (Miltown, Equanil): Perhaps the most widely used tranquilizers, these are known to produce drowsiness, muscular weakness, diarrhea, and skin reactions. In some cases they acually make the person taking them more tense and anxious.

One fact holds true for all medicines of the tranquilizer group: they interfere with the individual's ability to react. While this may be desirable in calming over-active persons, it is not desirable where the ability to react is as important as it is in flying.

Tranquilizers, barbiturates and antihistamines are prohibited for those on flying status in military aviation because they act directly or indirectly on the organ most important to flying safety—the brain. This fact has been recognized officially in a recent change in regulations prohibiting their use by pilots within a period of 4 weeks of any flying duty. Certainly these drugs are valuable and have a definite place, but that place is not in the pilot who is going to fly. Many drugs do not have a name sounding anything like antihistamine, for example. Therefore, the best rule to follow is, "Consult your doctor . . . and NO self-medication!"

From, Flight Safety Foundation



"Starboard 3 and 4 firing okay . . ."

(Plane Facts)

Along the Line . . .

Here and There With Air Line Pilots at Work and Play

Public Affairs Interest Lead Pilot To Candidacy

AIR LINE pilots, as a particular group, long have had a reputation as being enterprising, industrious men —they not only keep on top of the exacting duties and responsibilities of their profession, many of them have enough energy left to engage in other activities also requiring exceptional knowledge or skill.

These are men like Capt. Tom McManus of Northwest Airlines, a line pilot who not only meets the demands of regular flights between his home base in Seattle, Wash., and the Orient but also finds time to be extremely active in public affairs, especially those involving aviation, on local, state and national levels.

Now he has been drafted by aviation interests in Seattle to run for public office—that of Port Commissioner of the Port of Seattle, a three man policy making body which is responsible for the operations of the $43 million dollar sea and air shipping facilities in the Seattle Metropolitan area.

Need For Pilot

The reason the civil aviation interests in Seattle want the genial but outspoken 42-year-old air line pilot on the Port Commission is that it will give them representation and a voice on a board that long has been composed of men whose experiences mainly have been in the maritime fields.

The aviation industry in Seattle believes that it should be better represented on the Port Commission because the Seattle-Tacoma airport contributes a heavy share of the income for the operation of all port activities.

Captain McManus, his backers believe, is well qualified for the position. In addition to his professional experience, he long has been considered an authority on public issues in Washington involving aviation matters.

These activities include testimony pro or con on local and state legislation effecting aviation directly or indirectly, air safety, aviation gasoline taxes, and many matters pertaining to the port. Acquainted with Governor Rosellini of Washington, McManus has often been called upon by the governor for the pilot's viewpoint on aviation problems.

Capt Tom McManus

McManus, too, has spoken out often on matters directly affecting the pilot—like the campaign he helped wage in Congress against an increase in CAA physical exam fees to $20. At present he is campaigning on a national scale for an air line pilot representative in the new Federal Aviation Agency policy making structure.

Flying At 13 Years

An insight into Tom's energetic personality may be gained from his background. A Californian by birth, he showed such an early interest in aviation that he obtained a student flying permit when he was 13 years old. He soloed on his 14th birthday in an airplane he built himself. It was of primary glider design, powered with a Henderson motorcycle engine, pusher propeller, mounted on top of the wing.

McManus hopped passengers, ferried cargo, and dusted crops until the CAA finally caught him for conducting such activities at such a tender age.

Along with the flying bug at this age, Tom also got into automobile and motorcycle racing. This pace rendered school going so dull that he quit when he was 17, and shipped out for two years as an ordinary and able bodied seaman for the Oriental & Oceanic SS Co., in the Orient and Middle East.

Two years of seagoing life was enough, however, and he returned home to take on day and night school to make up his educational time. Then he was awarded a scholarship at Northwestern University where he majored in mathematics, and managed to win the Shell National Intercollegiate Flying Competition in 1939.

Northwest in 1942

The flying achievement won him a scholarship to the Boeing School of Aeronautics, from which he graduated to copilot for United. He joined Northwest as a copilot in 1942, and became a Captain less than a year later.

During World War II, Captain McManus flew ATC for 26 months in Alaska and the Aleutians, and later flew the Korean air lift.

Married on Feb. 29, 1944—good for one anniversary every four years—Captain and Mrs. McManus have two children, a boy, 12 and a girl, 11. He is a Mason, a member of the Rainier Golf & Country Club, and, of course, a member of the Port Committee of the Seattle Municipal League.

Aerodynamic Truth

(Sam Saint, air line pilot and author, wrote the following for American Aviation. His brother, Nate, also was an air line pilot before becoming a missionary.)

When word came out of a remote jungle area in eastern Ecuador that missionary Betty Elliot was in contact with three women of the savage Auca Indian tribe—the tribe that had killed her husband and four other missionary men less than two years before, concern for Betty's safety was immediate and fully justified. Her husband and his four companions had been struck down by Auca spears just two days after a

friendly contact with two women and a young man of the tribe.

When the news of Betty Elliot's precarious position reached the Missionary Aviation Fellowship Base some 50 air miles away, Hobey Lowrance (a former Reserve Captain for American Airlines and now a missionary bush pilot in Ecuador) rolled out his bright yellow Piper. Quickly he loaded aboard a large reel of phone wire, a canvas bucket and two field telephones. Hobey flew a beeline for the Oglan River where Betty was known to be.

As he flew he began to reel out the canvas bucket on the end of the twisted phone line. In the bucket was one of the phones. By the time he arrived over the jungle clearing the bucket was trailing some 1,500 feet behind the airplane. In the clearing a thousand feet below Betty's tall white figure waved. He saw the Indians watching.

Circles Clearing

Hobey put the Piper into a fairly tight circle over the clearing. At first the bucket on the end of the wire followed the airplane in its orbit. Soon

(Continued On Page 20)

ATC For Civil Jets . . .

(Continued From Page 4)

c. Figure 2 represents the composite performance of various types of aircraft-engine combinations; as an example, an aircraft with the large J-75 engines will tend to have better climbing performance than the same type of aircraft equipped with the lower-thrust J-57 engines.

Basically, the jet airplane is a high-altitude, high-speed machine. When operated at either low altitude or low speed, its efficiency is greatly reduced. For a given air temperature and aircraft weight, there is a definite optimum altitude at which the aircraft will be able to operate at its highest efficiency (lowest specific fuel consumption or least gallons per mile). In common with the rate of climb, the optimum altitude is increased if either the temperature or the aircraft weight is decreased. Because of the large number of interacting variables, flight planning for a civil jet operation will be an extremely complex job. At least one air line plans to handle this chore through the use of a large electronic computer.

Getting Under Way

A typical new civil jet will burn off 1000 pounds of fuel in just four minutes of taxiing. For this reason, pre-takeoff cockpit checks will be completed before the engines are started. It will probably be common practice for pilots to secure their ATC clearance before leaving the ramp. Once under way, they will prefer to taxi into takeoff position as soon as possible. No engine warmup will be required. However—and this may slow down airport operations a little—about ten seconds will be required for a static thrust check at full power before the pilot releases the brakes for takeoff. This check must be performed in takeoff position to avoid the huge fuel expense of "revving up" the turbines twice. However, the effects of this ten-second dead time can be reduced by letting the jet pull into takeoff position before the runway has been fully vacated by a preceding aircraft.

Climb And Cruise

For highest efficiency, the aircraft should climb immediately to the optimum altitude, and cruise as close as possible to the optimum altitude until it is time to start descent to the destination airport. As fuel is being burned off at a rapid rate, the optimum altitude gradually increases during flight. Ideally, the aircraft should be allowed to climb gradually (around 50 feet per minute) to coincide with the rising optimum altitude. However, the use of this "drift-up" technique would practically rule out the use of altitude separation between such aircraft in the ATC system.

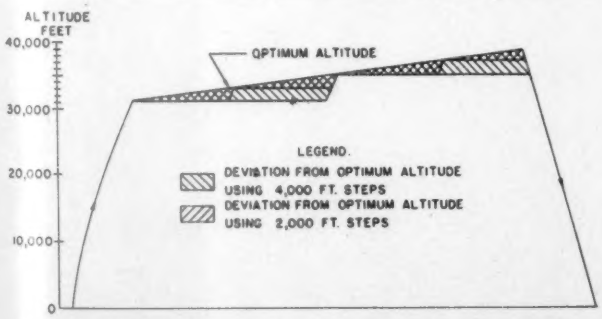
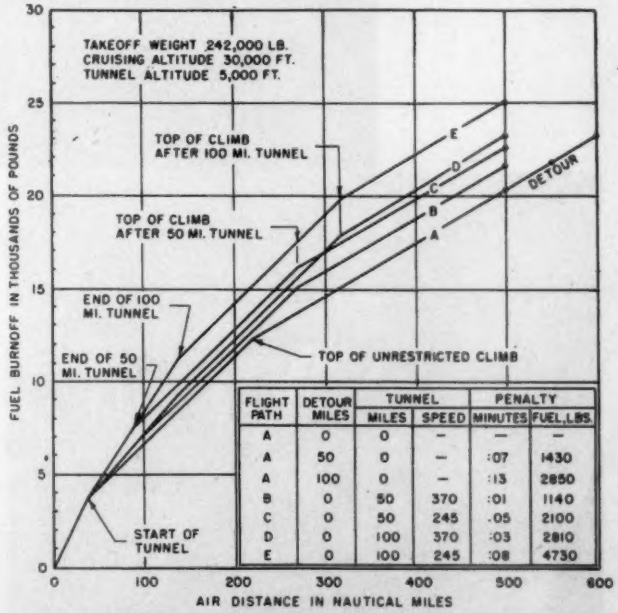


Fig. 3. Possible profiles for coast-to-coast operations.

One solution which appears satisfactory will be for the aircraft to use a stepped climb, as shown in Fig. 3. On a typical coast-to-coast jet flight, the use of a single 4000-foot step (two-level) cruise would inflict a three per cent fuel penalty over the drift-up technique. By using three 2000-foot steps (four levels), the aircraft would remain closer to the optimum altitude, and would suffer less than a two per cent penalty over the drift-up technique. It is interesting to note that the fuel penalty for a typical new jet will be about 1000 pounds per hour for each 4000-foot deviation from the optimum altitude.

Some of our busiest terminal areas are surrounded by other airports, airways, restricted areas, or terrain obstructions that will prohibit the use of unrestricted climbs directly on course. In some cases, there will be only one alternative—either to "tunnel" the aircraft out at low altitude until clear of the restrictions, or to climb it out in some other direction before proceeding on course to destination.

Figure 4 is one of a series of Howgozit (fuel versus distance) charts which are being prepared in connection with



FLIGHT PATH	DETOUR MILES	TUNNEL MILES	TUNNEL SPEED	PENALTY MINUTES	PENALTY FUEL LBS.
A	0	0	—	—	—
A	50	0	—	:07	1430
A	100	0	—	:13	2850
B	0	50	370	:01	1140
C	0	50	245	:05	2100
D	0	100	370	:03	2810
E	0	100	245	:08	4730

Fig. 4. Effect of certain ATC restrictions on a typical civil jet departure.

SCENES at ALPA's new regional offices in Coral Gables, Fla. Top center, reading left downward: President Sayen in office; hallway from lobby to offices; exterior view, and lobby with reception desk.

ALA's Regional Offices Coral Gables, Fla.

THE AIR LINE Pilots Association new regional offices in Coral Gables, Fla., opened last December, has become the center of ALPA activity in the Southeast section of the country.

In a building purchased by ALPA for $110,000, the spacious offices provide ample space for varied activities and simultaneous meetings.

Along a hallway extending from the lobby are five offices for LEC and MEC chairmen, separate offices for the Regional Vice President, and the First Vice President of ALPA, and offices for the secretaries, Ann McElhiney and Isabel Moe.

The offices also include a spacious conference room of 1,000 square feet area which can be divided into two rooms. It has a raised rostrum and a public address system. All the offices are air conditioned.

Interior furnishings include carpeting, cork-tone tile, wood and glass paneling, flourescent lighting, murals,

SPACIOUS conference room, left, at new ALPA regional offices; another view of the lobby, and Capt. William J. Barron (NAL), receiving jet airliner trophy from President Sayen for work on the project. Bottom center is ALPA executive committee meeting.

ALA's
on Office
Gales, Fla.

flower boxes and new furniture.

Each air line council using the facilities allocates from its allowable monthly expense authorization $1 per month per member as a rental payment. This currently amounts to $1,200 a month. At present Braniff, Delta, Eastern, National, Pan American, Panagra, and Riddle air lines maintain council quarters in the offices.

The offices were constructed and furnished for about 50 per cent of the estimated costs and much credit must go to pilots domiciled in the Miami area who volunteered their time to work on the project. Of these volunteers, Capt. William J. Barron (NAL), was extremely active.

The building, which has a 155 foot front and is 104 feet deep, also contains light business establishments. Rentals from these establishments amount to approximately $1,000 per month.

a simulation study of ATC restrictions. The objective of this study is to develop a valid basis for planning or control decisions in cases where a choice must be made between a certain length of tunnel at a certain altitude, versus a certain length of detour to obtain an unrestricted climb. It should be emphasized that the comparative results shown in Fig. 4 may not always hold true throughout the ranges of the variables which may be explored. Although this study has not been completed, results indicate:

1. Tunnel altitude should be as high as possible, and the length of the tunnel as short as possible, to reduce the deviation from the optimum flight path;
2. Detours represent wasted mileage, with high penalties in fuel and flight time;
3. A significant fuel penalty results if airspeed within the tunnel must be reduced for any reason. In some cases, overtaking problems may require jets to slow down while tunneling through congested areas at low altitudes.

The Big Squeeze

The capacity of an air traffic lane can be expressed neatly by the formula N=V/S, where N=Number of aircraft per hour, V=average velocity of aircraft in knots, and S= average separation between aircraft, in nautical miles. Inspection of this formula will show that the capacity can be increased if either the velocity is increased or the separation is reduced. If we assume that these two quantities are fixed, the total capacity of an airway system ultimately depends upon the number of independent traffic lanes which can be operated simultaneously.

This leads us to what may be the most serious problem in the economical operation of jet aircraft—the scarcity of desirable operating lanes.

The number of desirable cruising lanes is reduced first by the sensitivity of the specific fuel consumption to any deviations from the optimum cruising altitude. A second limitation is caused by the inherent errors in the types of altimeters presently in use. At the present time these errors dictate the use of 2000-foot vertical separation at altitudes above 29,000 MSL. This restriction imposes a 50 per cent reduction on the number of cruising levels available in the desirable jet operating region.

A further limitation in the number of potential routes is caused by azimuth errors in the VOR and TACAN navigation systems. In order to straighten high-altitude routes and to reduce the number of navigation aids which must be tuned in by pilots flying at high speed, certain facilities spaced 200 to 300 miles apart have been designated to form a network of high-altitude airways. However, because of the increased magnitude of the navigation errors possible between stations this far apart, the width of such airways must be increased proportionately with distance, up to about 30 miles. This will seriously limit the possibilities of providing suitable parallel lanes to separate the civil jets from each other and from the extensive amount of military traffic which already uses this airspace.

Approach Procedures

In common with other forms of traffic, air traffic has an inherently random characteristic; it normally tends to arrive in bunches, rather than at equally spaced intervals. Even though each aircraft in any given airway lane is spaced properly from preceding aircraft in such lane, the total input of aircraft from all lanes into an approach system follows what the statisticians call a Poisson distribution. This is an egghead expression which means that there are many more smaller intervals than larger ones.

The function of an approach system is to accept this input of random types of aircraft, from random routes and altitudes, at random times, and accomplish the following:

1. Establish an optimum arrival sequence, arranging the landing order in such a fashion that each aircraft in the group will have a landing time as close as possible to the time at which it would have been able to land, had it been the only aircraft in the air.
2. Properly space each aircraft behind the one ahead on the common path to the runway.
3. Guide each aircraft to a point where it can intercept the localizer or approach course and proceed inbound toward the runway.
4. Descend each aircraft from its entry altitude to an altitude at which it can intercept the glide slope for an approach.
5. During this entire operation every aircraft must be properly separated from every other aircraft. This implies the use of at least three miles horizontal or 1000 feet vertical separation at all times.

The ultimate objective of the approach control system is to adjust the arrival time of each aircraft so that it

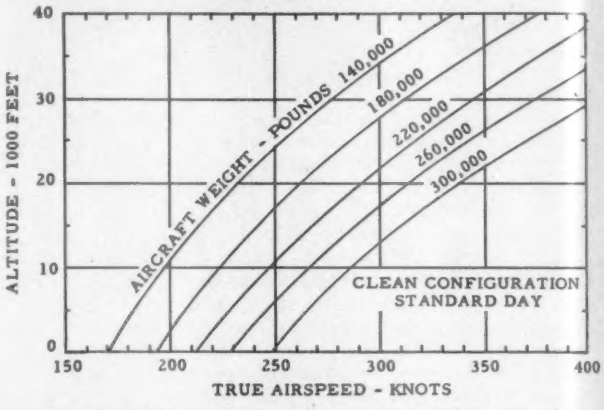


Fig. 5. Holding speeds of a typical civil jet aircraft.

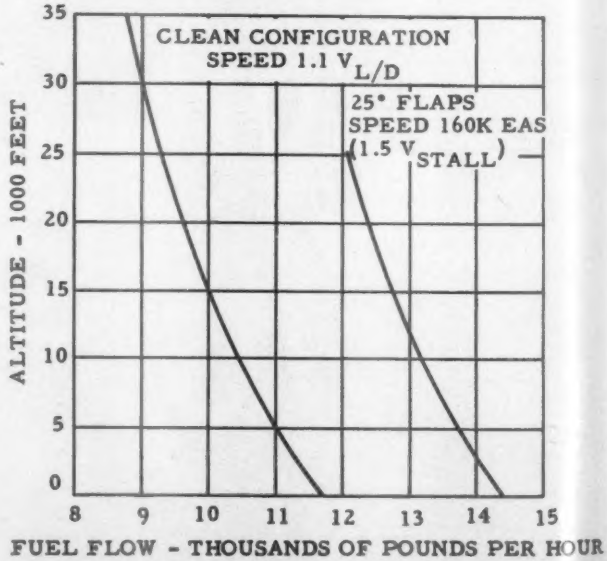


Fig. 6. Holding fuel consumption of a typical civil jet aircraft at maximum landing weight (190,500 lbs.)

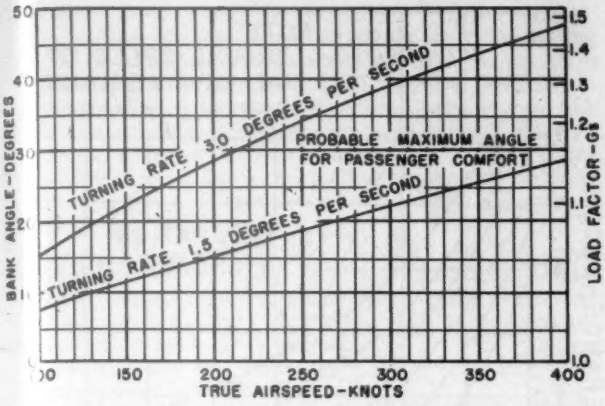


Fig 7. Relationship between true airspeed, turning rate, turning radius, bank angle and load factor.

me hes properly into the stream of arriving traffic, in an orderly landing sequence. There are four basic procedures for adjusting the arrival time of an aircraft: (1) Holding; (2) Path Stretching; (3) Velocity Control, and (4) Pre-assigned Departure Time.

All of these procedures are being studied in connection with their special application to the control of jet aircraft. Some of the most important points which have emerged from our approach control simulation studies are detailed.

Holding

Where jet aircraft are concerned, the use of holding patterns to absorb delay presents a number of closely interrelated problems, which probably can best be explained through the use of aircraft performance charts. Figure 5 indicates the holding speeds of a typical civil transport. Each curve defines what is actually a constant equivalent airspeed for a certain aircraft weight condition. However, the reduction of air density with altitude causes the true airspeed to increase at the rate of about two per cent per thousand feet of altitude.

The basic disadvantage of high holding speeds is the large amount of area which is required to contain a single

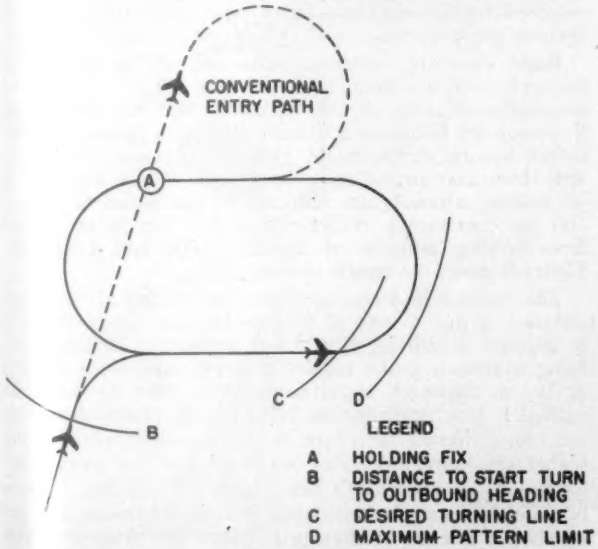


Fig. 8. Use of distance information to reduce holding airspace.

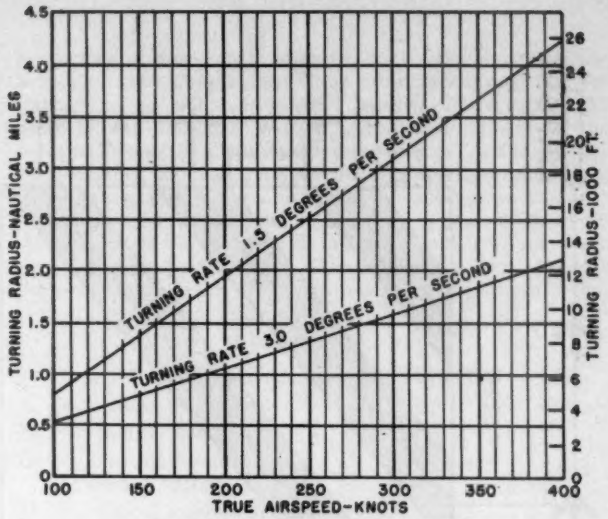

TURNING RADIUS-NAUTICAL MILES
TURNING RADIUS-1000 FT.
TURNING RATE 1.5 DEGREES PER SECOND
TURNING RATE 3.0 DEGREES PER SECOND
TRUE AIRSPEED-KNOTS

Fig. 9. Effect of jet holding altitude on communications and traffic flow.

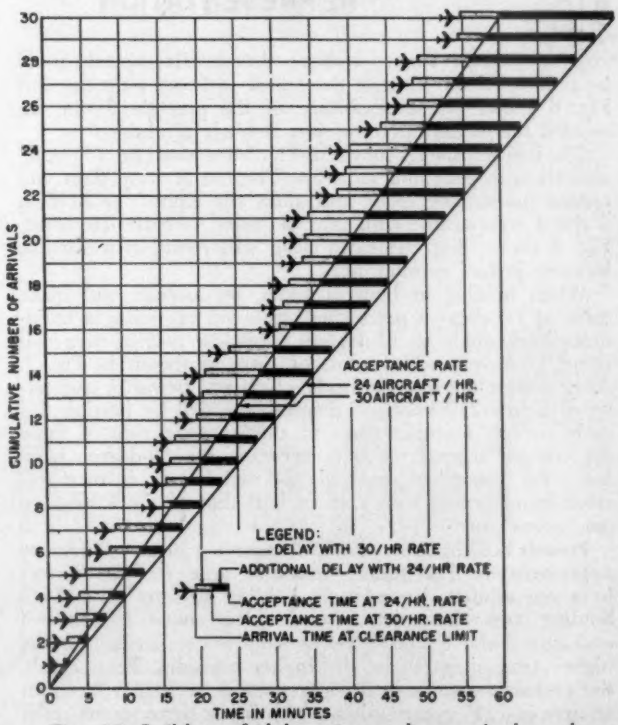
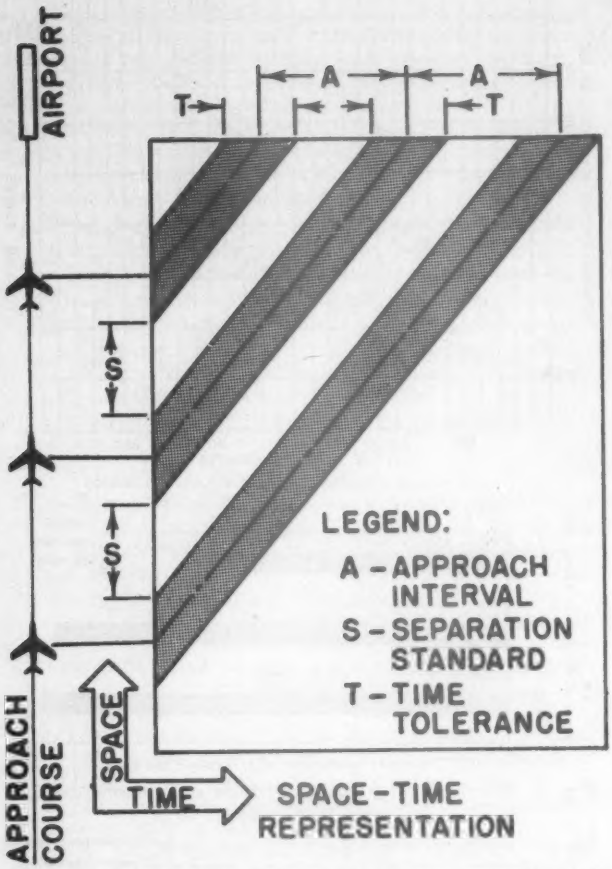


Fig. 10. Buildup of delays to random arrivals under saturated traffic conditions.



holding aircraft. Figure 5 shows that holding speeds could be reduced if the aircraft descended to lower altitudes, but Fig. 6 shows the disadvantage of the procedure—the increased fuel consumption of jets at lower altitudes.

The holding speeds shown in Fig. 5 are based on a "clean" aircraft with gear and flaps up. The use of wing flaps will reduce the stalling speed and allow the aircraft to hold at a speed comparable with that of piston aircraft. However, Fig. 6 shows that the extra drag will result in a sizeable increase in fuel consumption.

When holding at high altitudes, jet aircraft will make turns at 1.5 degrees per second, to avoid exceeding a maximum bank angle of 30 degrees. This low rate of turn will result in a very wide radius of turn, as shown in Fig. 7. After descending to an altitude which will permit a true airspeed below 210 knots, it theoretically will be possible for such aircraft to make turns at the standard rate of three degrees per second without exceeding the 30-degree bank limit. For any given airspeed, the higher rate of turn will result in a turning radius about half that of the 1.5-degree per second rate.

Present holding area standards reserve a block of airspace approximately 132 square miles in area for an aircraft in a one-minute, low-altitude holding pattern. The TSO holding area dimensions are doubled above 19,000 feet and tripled above 29,000 feet in order to compensate for the higher true airspeeds at the higher altitudes. As a result, the present two-minute holding pattern at 30,000 feet uses an area of 1245 square miles, which is just three square miles less than the area of the State of Rhode Island. However, actual radar checks of military jet holding operations indi-

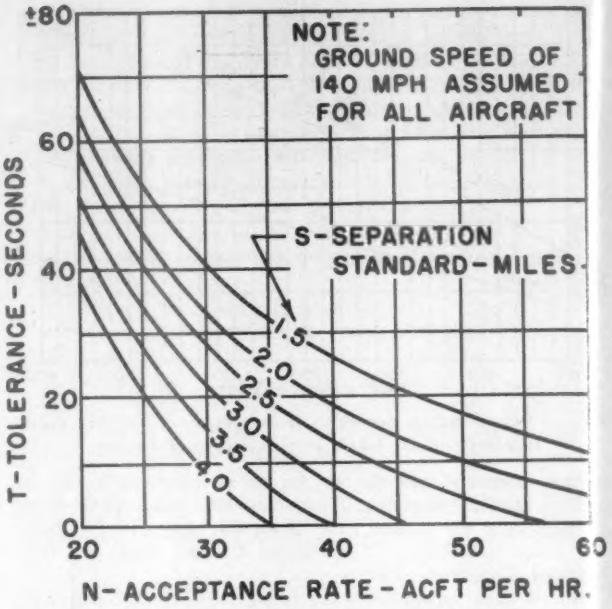


Fig. 11. Relationships between acceptance rates, separation standards, and time tolerances required for approach system.

cate that although most aircraft stay well within the length of the present holding airspace reservations, some of them get outside laterally, particularly in overshooting the holding area on their original entry from certain directions.

Already the airspace reserved for holding operations puts a rough restriction on airway operations in the vicinity of complex terminal areas. From the ATC standpoint, we can hardly afford to have the areas increased in size. A better approach to this problem would be to develop new flight techniques to permit the pattern size to be reduced. Figure 8 illustrates a DME navigation technique which has worked out well in simulation, to reduce the amount of airspace required for holding. It appears that such procedures will become more necessary with the advent of civil jet aircraft.

Based on early experience with military jet aircraft, it formerly was considered essential that all jet holding be accomplished at an altitude of 20,000 feet and above, and that each jet be issued a definite landing sequence number before leaving that altitude. However, dynamic simulation tests show that airport acceptance rates can be increased if jet holding altitudes are reduced. In one series of tests, a 100 per cent sample of jet aircraft was fed to an airport from holding altitudes of 20,000, 10,000 and 4,000 feet. Figure 9 shows the results of these tests.

The increase in acceptance rates, as holding altitudes are reduced, is due to several factors. It takes about 40 miles to descend a civil jet 20,000 feet at normal descent rates. Long approach paths require a large number of aircraft to be on approach simultaneously in order to keep the approach lane operating at full capacity. Tests show that the more aircraft there are in the approach pattern, the higher the communications workload and the more inaccurate is the controller's final approach spacing. This is because the controller's attention is divided between a larger number of aircraft so that he has less time to do a precise spacing job. In addition, longer common paths increase the opportunity for deviations in speed to affect the spacing

between successive aircraft.

The normal change in true air speed, while descending from high altitudes at a constant indicated air speed, is another problem which is intensified by the use of high approach altitudes. This factor makes prediction and spacing operations extremely difficult for the radar controller. Simulation tests show that all of these problems can be reduced by having aircraft leave the holding fix at low altitudes where normally they can be slowed almost to approach speed.

Figure 10 shows the importance of a relatively small change in airport acceptance rate on aircraft delays under saturated traffic conditions. Under heavy traffic conditions, the increased acceptance rate made possible by reducing the holding altitude of jet aircraft will more than compensate for the extra fuel consumption of such aircraft while holding at lower altitudes.

It now appears that the main penalty for low-altitude holding is not the additional fuel consumption, but the reduction in available range in case the aircraft gets down to low altitude and then has to divert to its alternate airport. The high fuel consumption in climbing back up to a suitable cruising altitude can cost about 150 miles of available range, compared to the range the aircraft would have had if the pilot had decided to divert before he left 20,000 feet in the first place. However, high-altitude holding does not eliminate this risk, as the weather still can go below authorized landing minimums during the time (usually 8 or more minutes) required to make an unrestricted descent from 20,000 feet.

In Fig. 10, the number of aircraft which are being delayed (the stack size) at any time, can be determined by counting the number of delay bars which are crossed by the vertical line at any particular time in question. This feature makes it possible to analyze the effects of a sudden closing of the airport on the various aircraft involved.

Suppose, for example, that 30 aircraft, including a goodly proportion of jets, expect to arrive at the airport within the next hour. The weather conditions are deteriorating, and are forecast to go below authorized landing limits within the hour. Should the jets be held at high altitude, restricting the acceptance rate to about 24 aircraft per hour, or should they be descended en route, to feed off the holding patterns at low altitude and thus maintain a high acceptance rate?

Assume that the airport finally goes below limits at 47 minutes after the hour, and that all aircraft which have not landed by that time must be diverted to their alternate airports. The effects of this situation on the aircraft concerned are listed in Table I.

TABLE I

AIRCRAFT DELAYS AND DIVERSIONS*

A. Jet holding procedure	High Altitude	Low Altitude
B. Acceptance rate, aircraft/hr.	24	30
C. Number of aircraft landed before :47	18	23
D. Number of aircraft diverted to alternate airport	12	7
E. Total delay to all aircraft before :47 minutes	199	96
F. Number of aircraft which held but did not complete approach	7	2
G. Total holding time of aircraft in line F, minutes	65	10
H. Maximum delay to any aircraft in line F, minutes	13	7

*See Fig. 10.

In any case, the pilot would have to make a decision before he left 20,000 feet as to whether he had enough fuel to risk a possible diversion from low altitude in case the weather closed in before his landing. If the low-altitude holding procedure were in use, this decision would have to be made 10 to 15 minutes earlier than necessary with the high-altitude procedure. Once the decision is made to descend below

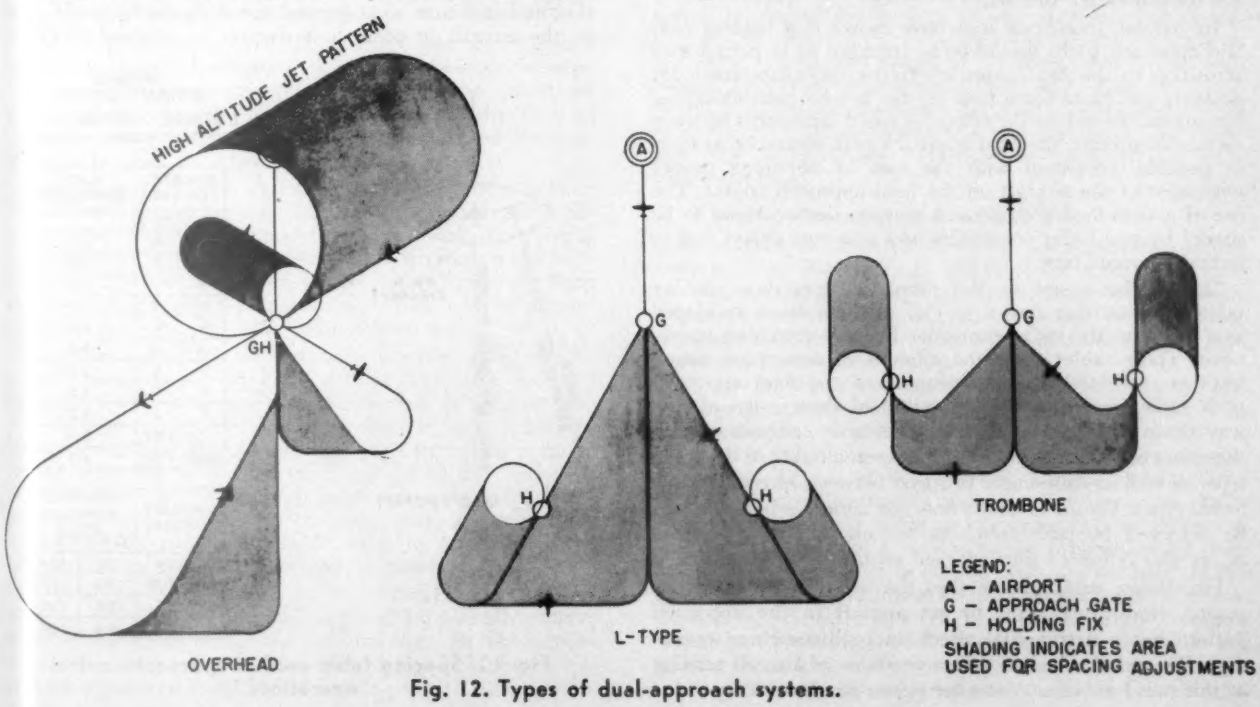


Fig. 12. Types of dual-approach systems.

20,000 feet, however, the probability of holding in vain and having to go to the alternate anyway is greatly reduced if the low-altitude procedure is adopted. Therefore, under such conditions, this strategy appears much more desirable from the viewpoint of probability of successful flight completion, as well as for purely economic reasons in minimizing delays to all aircraft concerned.

Path Stretching

The technique of controlling the length of a flight path, through the issuance of heading instructions to the aircraft, is known as path stretching. Used in conjunction with a properly arranged feeding system, this useful radar technique permits the controller to adjust the spacing between successive aircraft with a high degree of precision. As shown in Fig. 11, the airport acceptance rate depends directly on the degree of control precision which can be attained.

Figure 12 shows a few of the approach system configurations which have been tested during the jet simulation study. The overhead pattern shown on the left is an improvement over the conventional military jet teardrop penetration pattern. Although the teardrop pattern works satisfactorily for isolated aircraft, it is poorly adapted for high-density approach operations, since it provides no room for adjusting the spacing of the jet aircraft behind the preceding aircraft. Simulation tests prove conclusively that the provision of a base leg (a segment of the approach path approximately 90 degrees from the final approach) is essential for the attainment of precision in manual radar approach spacing operations.

The double overhead pattern shown in Fig. 12 permits the segregation of jet and piston approaches on opposite sides of the final approach course. This feature simplifies control operations somewhat by minimizing overtaking problems in the maneuvering area. The double-L and the trombone patterns shown in Fig. 12 have been developed to a high degree of refinement during the past several years of simulation, and have been found to be well adapted for the control of jet aircraft.

In general, simulation tests have shown that holding fixes and approach paths should be so arranged as to permit easy transition to the final approach course, adequate room for descent, and space for a base-leg for precise path-stretching operations. To reduce the effects of speed differences between successive aircraft, the final approach path should be as short as possible, consistent with the ease of obtaining proper alignment of the aircraft on the final approach course. The use of a twin-feed arrangement permits the workload to be shared by two radar controllers and also cuts delays due to aircraft descent time.

During the course of the simulation program, spacing tables, such as that shown in Fig. 13, have been developed as a guide to the radar controller in path-stretching operations. These tables show the amount of separation which must be provided at the beginning of the final approach path to insure a positive separation of three miles all the way down the final approach. The table compensates for the effect of deviations in speed between aircraft of the same type, as well as differences in speed between aircraft of different types. Figure 14 shows how the desired separation can be achieved by path-stretching techniques, using a series of circular reference lines marked on the radar display.

Simulation tests indicate that the use of 1.5 degree per second (half-rate) turns by jet aircraft in the approach pattern has a detrimental effect on path-stretching operations. The relative lack of maneuverability of aircraft turning at this rate forces the controller to use much more room for path-stretching operations and forces him to peel aircraft off the holding pattern earlier, to make sure they will be in a position for radar spacing operations at the proper time. This forces the controller to use much more room for path-stretching operations and also requires him to commit himself earlier on every decision he has to make.

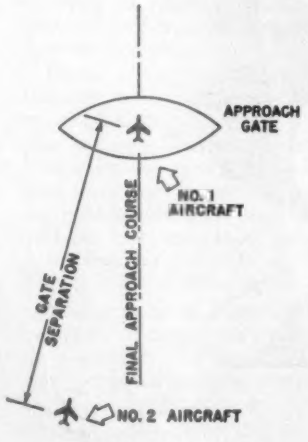
In addition, the increased length of the approach pattern requires more aircraft to be in the pattern simultaneously in order to keep the final approach path operating at full capacity. The additional aircraft increase the radar vectoring and communications workload and further divide his attention. As a result, the spacing accuracy possible with path-stretching techniques is reduced, and the acceptance rate suffers accordingly.

Tests show that the entire approach-spacing operation can be simplified immensely if the aircraft in the approach pattern can be slowed to a speed at which they can make standard-rate (three degree per second) turns.

Velocity Control

Whenever the traffic input exceeds the acceptance rate, delay is inevitable. From the ATC standpoint, the use of holding stacks forms a convenient reservoir of excess aircraft requiring no navigational guidance by the controller, and very little controller workload to keep separated from each other. However, holding stacks sometimes tie up valuable air space within the terminal area. As an alternate method, considerable simulation work has been devoted recently to an approach system incorporating preassigned landing reservations. This system uses velocity control during the last 100 miles or so of the flight to absorb most of the delay en route, and thus minimize holding operations within the terminal area.

A special computer known as ASCON (Arrival Scheduling Control) is used in this system. Starting with the optimum speed and deceleration program for each aircraft, the computer figures out what time the aircraft would arrive if it were the only aircraft in the area. It then looks at the list of landing reservations, picks the first available time slot, and indicates what ground speed should be made good by the aircraft in order to arrive on its assigned schedule,



OPTIMUM AIRCRAFT SPACING

DISTANCE, APPROACH GATE TO TOUCHDOWN, 5 MILES

AIRCRAFT SEQUENCE		GATE SEPARATION (MILES)
NO. 1	NO. 2	
S	M	5.1
S	F	5.5
S	J	6.6
M	S	3.1
M	F	4.5
M	J	5.8
F	S	3.0
F	M	3.5
F	J	5.2
J	S M F	3.0
SAME TYPE		4.0

AIRCRAFT CATEGORY		APPROX. APPROACH SPEED	
		M.P.H.	KT.
S	SLOW	120	104
M	MEDIUM	140	122
F	FAST	150	130
J	JET	180	156

Fig. 13. Spacing table used in approach control operations.

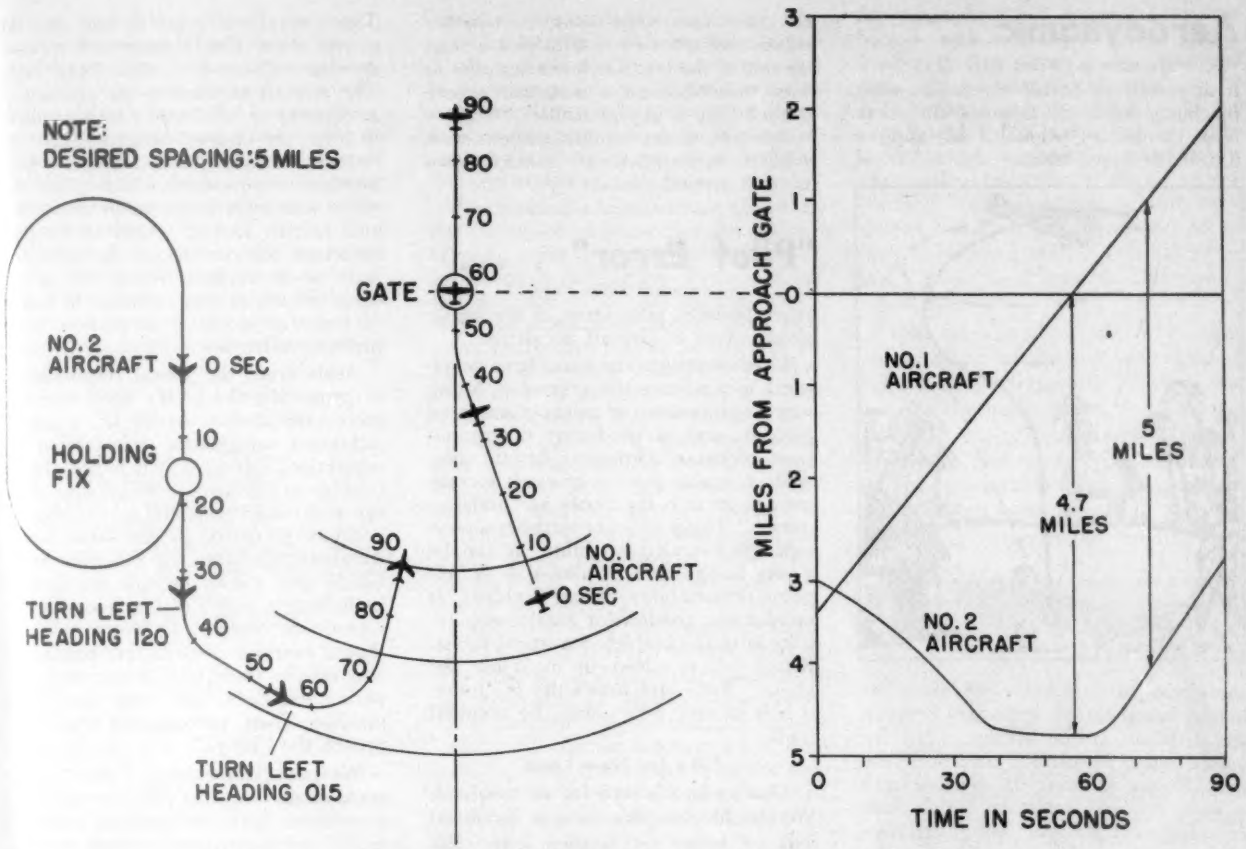


Fig. 14. Example of approach spacing procedure.

taking into consideration the normal deceleration program and approach speed of the aircraft.

Further progress reports can be inserted into the computer to provide speed adjustments for greater precision. In cases where the aircraft cannot fly slowly enough to absorb all the delay en route, the computer determines the time at which the aircraft should leave any holding fix on the way, in order to meet the assigned delivery time.

Simulation tests show that the establishment of a definite landing reservation for each aircraft does not, in itself, increase the airport acceptance rate. However, it is quite apparent that the "derandomization" of arriving traffic simplifies the approach control operation immensely by metering the flow of arrivals to a steady rate which can be accommodated easily by the radar approach system.

Tests indicate that the precision possible with velocity control alone is not as high as that attainable by path stretching. This is because the effectiveness of velocity control decreases progressively as the aircraft approaches the destination, while the usefulness of path stretching is maintained right up to the approach gate. For this reason, it appears that the use of offset approach courses, with the ability to make last-minute path-stretching adjustments if necessary, will still be desirable, even in a system which utilizes velocity control as a primary concept.

Test results show that the use of velocity control produces a very orderly flow of inbound traffic and drastically reduces holding operations within the terminal area. In high-density simulation tests, many jets are able to make practically unrestricted descents from 20,000 feet.

We should point out that these tests are being made primarily to observe the concept of velocity control in operation and to determine the system requirements for such an operation. The actual design of an operational system with enough information-handling capacity to do this job properly will require a lot of research and development in the fields of automatic tracking, computers, and data links, and therefore may be years away. However, the general idea looks very promising.

Preassigned Departure Time:

If we take the concept of setting up a definite landing reservation for each aircraft, and carry the scheduling (velocity) control back farther and farther from the destination airport we arrive ultimately at the stage where we are actually controlling the departure time in order to make good a definite landing reservation.

In view of the limited amount of information storage and processing capacity in our present manually controlled ATC system, the idea of preassigning departure times in order to master-mind the entire flow of traffic in advance may seem far-fetched at this time. However, with a general trend toward higher flight speeds and operating costs, the ability to absorb most traffic delay on the ground, prior to takeoff, may someday become a very attractive proposition for large jet aircraft with direct operating costs approaching $1,000 per hour. The realization of such a concept would of course depend on the development of a tremendously complex tracking, computing, and data-processing system. For this reason, it's a long way off in the future.

(Reprinted From Journal of Air Traffic Control)

Aerodynamic . . .

(Continued From Page 11)

it appeared to be off the inside wing tip, but going in the opposite direction. Now the bucket began to fall and, as it fell, to move toward the *inside* of

the circle. After about three turns the bucket hung almost stationary beneath the airplane at the vortex of an inverted cone. By careful control of the turn Hobey lowered the bucket until it came to rest almost at Betty's feet. *In a moment she was talking by telephone to an airplane flying overhead.*

The technique of lowering a canvas bucket to a stationary point on the ground was invented by my brother, Nate. He used it many times to contact isolated outposts where there were no airstrips and no radios. He once talked to the President of Ecuador over his plane-to-ground telephone. Week after week he and his companions lowered gifts to the Auca Indians, who had no other contact with the outside world. After a time the Indians began to return gifts in the bucket.

On January 8, 1956, my brother, Betty Elliot's husband and three companions were killed by these same Auca Indians when they attempted a friendly contact on the ground to tell these Indians of Christ and the Gospel.

How did Nate ever dream he could lower a canvas bucket quietly into a jungle clearing? We don't know. We know he felt keen frustration several times trying to decipher messages scrawled on a sandbar or trying to understand some pantomime performed desperately in a few seconds as the airplane flew over at tree-top height.

Nate invented and used his telephone from the sky. He picked up weights as heavy as 70 pounds. But he dreamed of other uses. One wonders whether others will discover how to pick a man up out of the sea? Or lower supplies to men marooned on a mountain where parachuting is impracticable? Or allow secure and secret communications with soldiers surrounded or isolated from normal ground contact?

"Pilot Error" . . .

(Continued From Page 5)

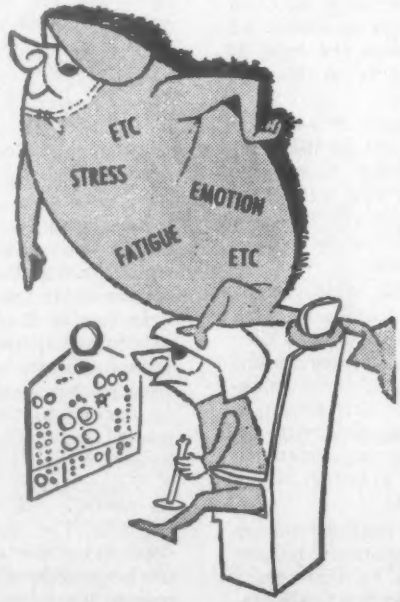
more politely, pilot error, is the major single cause of aircraft accidents.

Crash investigation teams have developed to a science the process of fitting together thousands of pieces of scattered aircraft, and in producing determinations of cause. However, despite their skills, a sizable portion of crash investigations go into the books as "undetermined." The pilot error statistics always tops the overall probability. It can be a very handy term. It allows us to pinpoint responsibility for an accident. It satisfies our passion for cataloguing results in neat, complete statistical tables. Better yet, it allows us to "close the books." But—and here's the *big* but—it tells us very little about the accident itself.

Time for New Look

That's why it's time for an overhaul. We should give pilot error a jaundiced look or, better yet, consign it to what the Navy boys call the "deep six."

In the first place, pilot error can't be the prime cause of any accident. What caused the pilot to err can be.



"Pilots occasionally react to . . ."

That's what we've got to look at—the casual chain. The factors which sponsor accidents. Cause is rarely a single item. The aircraft accident is the product of a sequence of influences which combine to form the disaster pattern. These influences include design features which invite error; routines which place the pilot in an accident-prone environment; and human factors which affect performance but over which the pilot has little or no control. Worse yet, all of these influences may combine in a way to make an accident inevitable. They probably often do.

Aside from the moral responsibility of protecting the pilot's good name, a more critical examination of causation influences would have direct force for correction. Admittedly, it is not always possible to examine wreckage and come up with valid answers as to why an accident occurred. By the same token, we shouldn't jump on the pilot error bandwagon merely because we succeed in linking a pilot's last actions with a subsequent disaster. In every case, we should examine contributing conditions and couple these with experience, experimental data, and logic insofar as possible. Then, perhaps, we would approach the "Why?"

We know, for example, that a pilot occasionally forgets, acts on mistaken perception, reacts to emotion, responds to "g" stress, operates a wrong control, misreads an instrument, or does any number of things which invite trouble. All these phenomena constitute pilot error, but most of them will be found related to the design—environment—human factors. As such, they demonstrate the pilot to be but a link in the causal, and not the chain itself. They demonstrate, too, that the human is an inherently variable machine, that man at his best has dire limitations and that human physiology falls short of the demands of machine technology. We cannot expect the pilot to be superman, and hang him if he falls short.

Changed Cockpit

Let's take a look at the co-pilot who goofed by pulling the wheels-up control at the pilot's "flaps-up" command. Investigation disclosed that this co-pilot had been trained on another type transport in which the flaps lever was in the same position as the landing gear control of the damaged aircraft. He had reflexly reacted to the stimulus of the command, "flaps-up," as he had initially been trained to do—a good example of the transfer of training.

Beyond this momentary "goof" lie some salient lessons in training and design. The major purpose of training is

to develop stable habits of response. A habit is an action which, by its nature, is removed from the conscious mind. It is a reflex response, mediated below the brain, hence is inflexible. Training consists largely of acquiring the ability to operate machines reflexly. Such learned patterns persist, despite later learning. Extreme re-training is necessary to extinguish them to a "safe" level. They are initiated by a given stimulus before complete awareness of the stimulus itself. For example, we hit the brakes of our car before we fully appreciate the emergency. Experiments show that in

"Vertigo"

moments of stress, or when the mind is otherwise engaged, the pilot may react to earlier training. This pilot did!

A pilot should be kept with the same model aircraft as much as possible. Intensive re-training periods should precede change from one aircraft to another and this should be followed by frequent "blindfold cockpit tests" to fortify the new learning.

On the design side, primary controls should be standardized as much as possible. Controls should differ in location and appearance. Further, a control should be so designed that its "feel" becomes symbolic of its action. If the landing gear control in question hadn't "felt" like "flaps-up" the co-pilot might not have carried through with the act of pulling it.

This simple transfer of training phenomenon (an inherent part of human learning) has been the cause of untold accidents. But do they reflect true pilot error? We might better blame the training procedures which fail to eliminate the earlier learning, or which failed to superimpose the new learned pattern to a stable degree. (And why, by the way, were two such controls transposed?)

Human Limitations

Take the pilot who flew his executive transport into the ground while the gyro-horizon indicator read "nose-up." On the surface, this seems an unforgivable pilot error. It's obvious he didn't really look at the indicator. Or did he? Again we are confronted with an area in which human limitations loom large. There is a definite limit to the amount of information the human brain can absorb and digest in a given time. This limit varies from person to person but seems to fall below even the high capacity demanded of the birdman.

Every time an instrument is added to the panel, we both increase the probability of error and slow response time, for both are a function of the size of the selection field. No human could hope to adequately cover each and every instrument which we manage to cram into modern aircraft. The pilot is assailed by myriads of instruments which variously require quantitative readings, qualitative readings, check readings, and tracking or setting, not to mention the mental acrobatics imposed by interpolation requirements.

When the executive pilot goofed, we might better have looked at the job we gave him to do. Can we fairly say it was the pilot's fault that he failed to extract the total information being thrown at him through a multiplicity of instruments, even when this was patently impossible? Or should we do something concrete about eliminating unnecessary information bearers and by simplifying those remaining? Why not give the pilot only what he has to know in terms of what he can use without interpolation?

"Good Instrument Display"

We have evolved a number of criteria for "good display." According to "the book," an instrument panel passes muster if it presents easily visualized data, can be read quickly, and can be read as accurately as necessary in the time allowed. But is this sufficient during stress or emergency? Remember, the pilot is no longer operating at his old, cool self. He's revved up, variable, open to error, subject to reflex, and all at once confronted with a multiplicity of tasks. Now how does the instrument panel look?

That takes us to the pilot who bailed out while in straight and level flight. A few years ago the word "illusion" was one for the psych books. But suddenly we're batting against it. Every time we produce a faster, higher-flying aircraft we step deeper into the aerial quagmire of "mistaken perception."

Man operates by information sup-

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plied by his sensory organs. All decision and response depend upon the accuracy of input data, or the interpretation of the data. Aside from the proverbial five senses, there are at least three others basic to aerial orientation: two in the inner ear and pressure senses distributed throughout the muscles, joints, skin, and internal organs. Their basic job is to place man's attitude relative to his environment. Unfortunately, they were not designed for sudden accelerations or radial flight. A pilot spinning to the left may sense himself turning to the right; a sudden positive acceleration may feel like climb, negative acceleration like a dive; a pilot in a vertical dive may sense he's in straight and level flight. Unintentional inverted flight isn't at all a rarity.

Visual Illusions

Read the instruments, did you say? Yes, this is about the best we can say. However, elaborate visual illusions also accompany sudden accelerations, tight turns, blind flying, or conditions in which the usual visual cues are absent. The eyeballs may move in slow sweeps with rapid "snap-back" (nystagmus); visual objects may seem to move in random fashion (autokinesis); lights may appear to split asunder. These are only a few of the numerous vertigo responses which are becoming more prevalent as aircraft designs advance. This is why the pilot ejected while in straight and level flight. Sure, he was straight and level—but he didn't know it and, under the circumstances, probably had no way of knowing it. Ever try to read a dial while your head's swimming? The pilot probably thought that he was going straight in— had to make what he believed was a life-and-death decision in split-second time.

Pilots (especially jet fighters) should receive concentrated vertigo instructions and demonstrations as an integral part of their basic training. They should be subjected to rotating chair and centrifuge devices. They should know the danger in shifting sight between instrument panel and the exterior visual field when the latter is poorly structured. They should be taught not to make sudden head movements, not to fixate instruments and to depend upon their instruments when their body senses are in disagreement. In short, pilot error involving vertigo may represent weaknesses in our training methods.

Ability to Respond

Some aircraft accidents result from the pilot's inability to respond quickly enough to an emergency situation. Such accidents should increase with increased performance, but we should not label them pilot error. After a visual stimulus strikes the eye, it requires somewhere in the neighborhood of 30 milliseconds to reach the brain. More time is required for recognition, integration, and decision, and more time yet for response. Then there is a final time lag before the aircraft responds to the changed controls. All of this means that an aircraft, especially a jet, may move hundreds of feet between the pilot's first visual awareness and his ability to affect aircraft performance. This baby shouldn't be left on the pilot's doorstep. Proximity warning devices may be one answer. Or means whereby the pilot is

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fed anticipatory information.

These are not the only influences to pilot error. Fatigue, lack of familiarity with route, equipment or procedure, "overload" or insufficient work load (thus tending toward preoccupation) are others. The roll call is long. But if we abandon the weird thesis that human capacity equals machine capacity, we will have made a long forward step. If we incorporate fully what we now know into the design of instruments, controls and personal gear, a longer step will have been made. Finally, if we improve and expand our training programs, and "know that the pilot knows" before he climbs into the tall blue, we will have made a giant step. Then watch pilot error statistics. I think we could predict a sharp drop.

(A former newspaperman and public relations practitioner, Mr. Sutton is a Research Engineer with the Human Engineering Group, Convair-San Diego. After Marine service, his interest in planes, people and psychology prompted him to an MS degree in experimental psychology.)

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